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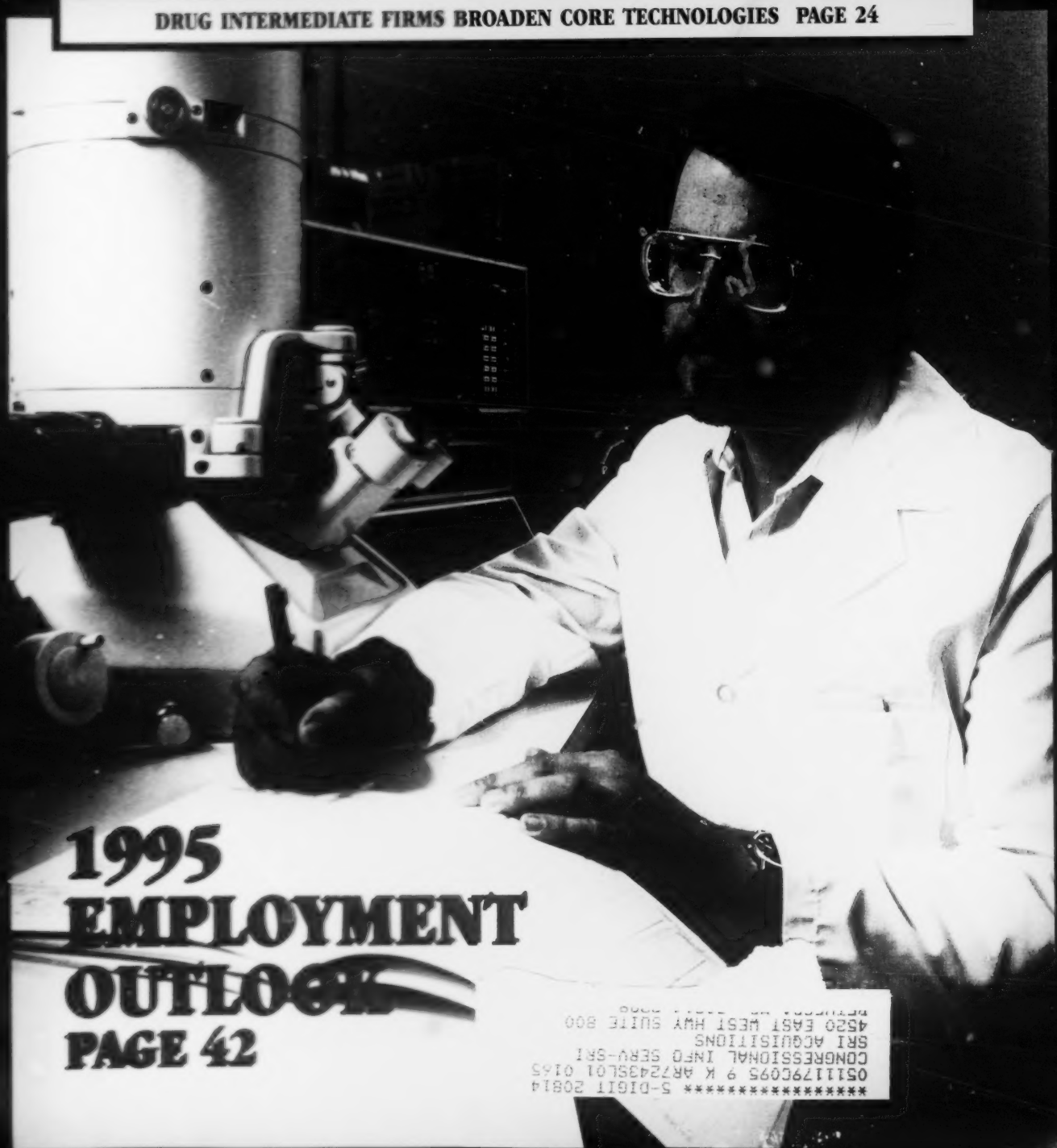
CHEMICAL & ENGINEERING NEWS

C&EN

OCTOBER 24, 1994

DRUG INTERMEDIATE FIRMS BROADEN CORE TECHNOLOGIES PAGE 24



1995 EMPLOYMENT OUTLOOK

PAGE 42

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CHEMICAL & ENGINEERING NEWS

C&EN

OCTOBER 24, 1994

NEWS OF THE WEEK

■ New data suggest that nitrogen radicals from the exhaust of supersonic aircraft may not pose as serious a risk to the stratospheric ozone layer as once thought. **Page 6**

■ Heavy rains and floods in the Houston area last week forced at least two chemical plants to shut down and halted chemical shipments in the Houston Ship Channel. **Page 7**

■ Monsanto draws fire on several counts as controversy continues to swirl around its recombinant bovine growth hormone. **Page 7**

■ Some 14 million Americans are routinely exposed to herbicides in their drinking water, according to a new environmental report. **Page 8**

■ The Office of Naval Research and Stanford University have settled a more than four-year-old dispute over payment and billing of indirect research costs. **Page 9**

■ A new program launched by NSF is aimed at raising the quantity and quality of bachelor degree graduates in science, math, and engineering at schools serving blacks, Hispanics, and Native Americans. **Page 9**

COVER: Dow Chemical senior research technologist records operating parameters of transmission electron microscope. Photo by Jeffrey R. Glenn

Volume 72, Number 43
CENEAR 72 (43) 1–80
ISSN 0009-2347

BUSINESS

Recovering economies and increased demand for production of gasoline oxygenates are leading to tighter supplies of methanol as its transformation to commodity status appears complete. **Page 13**

Most states had increases in personal income from the chemical industry in 1993, according to the Commerce Department. **Page 16**

GOVERNMENT

Upcoming elections are not likely to change the science-related leadership in Congress, although some changes for science and technology subcommittees are in store. **Page 18**

Bill authorizing compensation to veterans disabled by Gulf War syndrome has been approved by Congress, as cause of illness continues to be sought. **Page 22**

SCIENCE/TECHNOLOGY

Producers of pharmaceutical ingredients and intermediates expand chemical capabilities, strengthen basic technologies to adapt to changing demands within the drug industry. **Page 24**

A new computer workstation packs the power of a supercomputer into a desktop machine at a fraction of the cost. **Page 34**

A plasmid DNA vaccine protects mice against infection by the parasite that causes malaria and raises hope that an effective malaria vaccine is feasible. **Page 36**

EDUCATION

Courses that address ethical research practices in chemistry and related sciences are beginning to be offered by some university chemistry departments. **Page 38**

EMPLOYMENT OUTLOOK

C&EN's annual look at the job market finds it opening up a bit for new chemistry graduates, but job seekers are advised to consider a broad range of options. Page 42

LETTERS 4
EDITOR'S PAGE 5
CONCENTRATES
Business 10
Government 17
Science/Technology 23
THE DEPARTMENTS
ACS News 66
People 78
Newscripts 80

Chemical & Engineering News

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LETTERS

Laboratory-based instruction

The article titled "Chemistry Curriculum Reform Focuses on Content, Technology, and Pedagogy" (C&EN, Aug. 29, page 35) is a landmark summary of research reports related to laboratory instruction in beginning-level college chemistry and also related to the nature of chemical education research. Unfortunately, the papers on these two subjects, presented at the 13th Biennial Conference on Chemical Education, as reported in the article, confuse the need to change the content of laboratory instruction with the need to reform the pedagogical approach to this instruction.

One presentation given at the conference did differentiate between these two needs; however, it was not included in the summary article. The presentation reported on the first phase of an extensive study conducted by a team of researchers at Temple University (F. Sutman, J. Schmuckler, A. Hilosky, and S. Rubin). In the study, instruction in 26 chemistry laboratory sessions in the U.S. and in Germany was analyzed by using an instrument designed and validated to describe pedagogical approaches.

The results of the study are most revealing because they indicate that although every laboratory instructor in the U.S. sample espoused primary significance to laboratory instruction, in no instance did assessment of student learning procedures reflect learning outcomes from the laboratory experiences. In the German population, however, assessment of learning was totally based on the laboratory component of the chemistry course.

In the U.S. sample, laboratory instructors devoted almost all of their teaching effort to listening to and answering students' questions about laboratory procedures. This left little or no time to devote to faculty-student interaction for explaining what students observed or to other higher order concerns related to chemical theory. This practice dominated the laboratory time even though students were expected to read and to understand the procedural steps for the laboratory experiment prior to entering the laboratory, and even though the commercially available printed directions included higher order questions, supposedly to be addressed during the post-laboratory instructional period. These questions were never addressed.

Even in the experimental chemistry courses (in the U.S.), developed through support from the National Science Foundation, the laboratory experiences were totally separated and unrelated to the lecture. In no instance did instructors develop lecture recitation as an outgrowth of the laboratory experience.

The laboratory and course instructors, whose instruction was analyzed, had only two professional contacts with pedagogical concerns: a subscription to the *Journal of Chemical Education* and infrequently reading a related article in C&EN. During the followup interviews to the analysis of laboratory instruction, they described how they had changed their pedagogical approach, when in fact all they had done was find new content to be taught in the same way.

Many other significant findings have evolved from this comprehensive research. Those who are interested in these findings are invited to contact the researchers or to look for future reports of the research in the *Journal of Chemical Education*.

Francis X. Sutman
Temple University and
Rowan College of New Jersey
Glassboro

Lewis Chiral?

The article on chiral drugs (C&EN, Sep. 19, page 38) includes the quote from Lewis Carroll, "Perhaps looking-glass milk isn't good to drink." I have always found myself using the same quote when beginning to lecture on stereochemistry. "Through the Looking Glass" was published in 1871, quite a few years after Pasteur had separated his tartrate crystals in 1848, but two years before van't Hoff's and LeBel's works dealing with the tetrahedral nature of carbon. Is it known if Carroll understood the chiral nature of Alice's question or was it just an offhand remark?

Eugene J. McDevitt
Siena College
Loudonville, N.Y.

Correction

• Oct. 17, page 4: The late physical organic chemist Saul Winstein, not Weinstein, was a professor at University of California, Los Angeles, not Harvard University.

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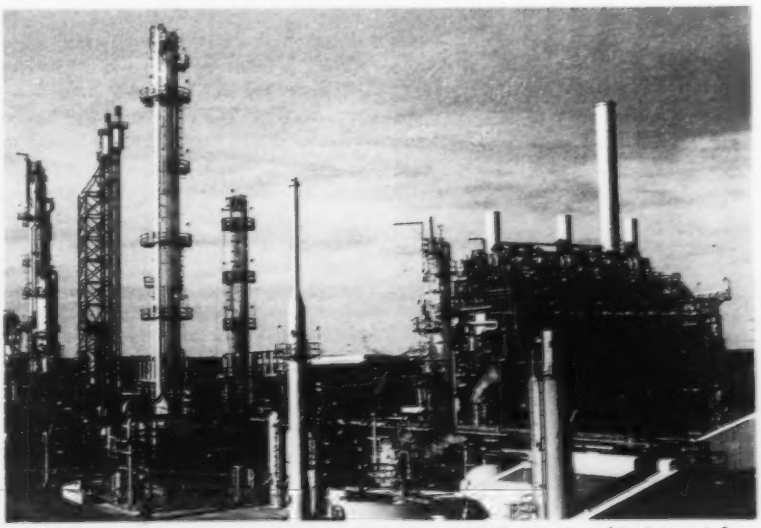
Methanol's Transformation To Commodity Status Stretches Supply

■ ***Recovering economies, increased demand for methanol in production of gasoline oxygenates lead to higher prices***

George Peaff,
C&EN Northeast News Bureau



Terra Industries entered the methanol market in June with the opening of its integrated methanol/ammonia facility in Woodward, Okla.

Methanol is undergoing a renaissance. Beginning in the U.S. in the fourth quarter of 1993, methanol has seen a transformation from a low-growth, low-priced, overly abundant commodity chemical into a high-demand, undersupplied, cost-price driven product. As the economic recovery has spread to the rest of the world, methanol demand has dramatically increased. This meteoric rise has been further sparked in the U.S. by increased use of methanol as an ingredient in gasoline oxygenates required by the federal government.

Increased demand has led to the consolidation of producers, a scramble to reopen existing capacity, addition of capacity via product conversion, and plans for various future capacity expansions.

Methanol fits alongside the other long-standing, major organic commodity chemicals—ethylbenzene, ethylene, ethylene dichloride, formaldehyde, propylene, styrene, terephthalic acid, and vinyl chloride. Methanol also serves both as a building block for many other chemicals—formaldehyde, acetic acid, and terephthalic acid—and as a solvent for many industrial uses.

Bruce Aitken, commercial vice president for Methanex, Vancouver, British Columbia, says the run-up in methanol pricing was first "based on the traditional uses of methanol such as acetic acid." Methanol prices jumped higher in August, he adds, when demand for use in methyl *tert*-butyl ether (MTBE) increased to meet U.S. wintertime gasoline requirements and the Environmental Protection Agency's new oxygenated fuel requirements slated to go into effect Jan. 1, 1995.

From a 50-cent-per-gal range in fourth-quarter 1993, barge price for methanol reached $1.30 per gal by mid-October, producer and industry sources say. "If you look at year to year, between 1993 and 1994, there's another 2.87 billion lb of methanol going into MTBE," Aitken states. He projects an additional 2.87 billion lb going into MTBE for 1994–95.

Aitken sees methanol being in short supply for the rest of 1994, and he believes the market will bid up the value of a commodity in scarce supply. Both methanol and MTBE display classic commodity characteristics.

A product gains commodity status when its use becomes an everyday necessity. Supply and demand may change over the course of time depending on the ups and downs of the economic cycle, but a central demand for a commodity product ensures its producer a continuous market for that commodity product.

Although a commodity product tends to garner lower prices because so much of it is produced, its bulk volume and necessity status perpetuate a continuous market. However, a weaker or stronger economy, introduction of new uses, emerging replacements, or a catastrophe may all have an impact on supply and demand.

About 27% of methanol produced in 1993 was used in MTBE. Methanol also serves as a key ingredient in production of formaldehyde, acetic acid, chloromethanes, methyl chloride, methylene chloride, chloroform, methyl methacrylate, dimethyl terephthalate, methylamines, acetic anhydride, glycol methyl esters, and numerous phosphorus derivatives.

MTBE's primary use is for blending into gasoline as either a replacement for lead-based octane enhancers or as an oxygenate to meet the cleaner burning gasoline standards set down by EPA under the Clean Air Act.

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In 1993, MTBE ranked ninth in terms of production at 24.1 billion lb, a 121% rise over 1992 when it was the 19th-ranked chemical in the U.S. according to C&EN's ranking of the Top 50 chemicals (C&EN, July 4, page 31). Methanol in 1993 was ranked 21st at 10.5 billion lb, a 30% rise in production over 1992 when 8.08 billion lb was produced. About 2.84 billion lb of U.S.-produced methanol went into the making of MTBE in 1993.

Global methanol supplies could be tight in 1995-96

Billion lb	1993[a]	1994[b]	1995[b]	1996[b]	1997[b]
Capacity	52.0	54.5	56.8	58.6	63.5
Demand	45.6	49.4	53.4	55.9	58.2
% utilization	88	91	94	95	92

a Estimate. b Forecast. **Source:** Crocco & Associates

According to Fred Peterson at Probe Economics, a consulting firm based in Millwood, N.Y., U.S. demand for MTBE was 19.9 billion lb in 1993, which would require about 7.22 billion lb of methanol to produce. However, since only 2.84 billion lb of the methanol produced in the U.S. went toward MTBE production, another 4.38 billion lb was imported for use in the U.S. to produce MTBE in 1993.

Peterson pegs U.S. MTBE demand by 2000 at around 67 billion lb. To meet that demand, 24.2 billion lb of methanol would be required. If EPA's 30% renewable oxygenate mandate survives, MTBE demand would be 46.9 billion lb, consuming 16.9 billion lb of methanol. A court challenge to EPA's ethanol mandate filed by several organizations representing the petroleum and methanol industries likely will be heard in late January 1995. Currently, ethanol is the only renewable oxygenate available to meet required demand.

Global demand for methanol will likely grow 6.2% per year through 1997, with methanol use in MTBE representing about half of that growth, according to a report by Crocco & Associates, a Houston-based consulting firm specializing in methanol.

Crocco estimates that worldwide methanol demand in 1993 reached 45.6 billion lb, with capacity at 52 billion lb and utilization at 88%. Forecasts predict demand to reach 49.4 billion lb for 1994, with capacity at 54.5 billion lb and a utilization rate of 91%. Currently, there are 33 methanol producers. By 1997, demand could reach 58 billion lb, with capacity reaching 63.5 billion lb and utilization at 92%, taking into account existing projects for new capacity and capacity expansions.

But in 1995 and 1996, Crocco forecasts capacity utilization could reach 94% and 95%, respectively, making methanol supplies tight and current pricing increases sustainable. Producers are unlikely to invest in large expansions despite greater demand, however, because they still remember both the low prices for methanol in the 1980s and early 1990s and the utilization rates ranging between 74 and 81%.

And because many existing plants are old, scattered shutdowns will also tighten supplies. For example, in late September Lyondell Petrochemical was forced to shut down its Channelview, Tex., methanol operation because of problems in one of the plant's synthesis gas units. The plant produces 4.2 million lb of methanol per day for use in MTBE. Production resumed on Oct. 6.

To further complicate the current tight supply, an explosion on Oct. 12 at Enron's Pasadena, Tex., methanol plant idled 2.72 million lb of daily production. Only minor injuries resulted, but production at that plant will remain shut down indefinitely as the company investigates the cause and resultant damage of the explosion. Methanex markets 40% of the methanol produced at the plant, with Enron utilizing 50% of the methanol at its neighboring MTBE facility.

Industry compensation for lost production as a result of plant shutdowns has been forthcoming, however. Terra Industries of Sioux City, Iowa, recently switched over part of one ammonia production plant to methanol production. Mike Drissell, Terra's manager of nitrogen products, explains that methanol producers are hesitant to spend $100 million to $150 million to add methanol capacity until the many side issues of fuel oxygenates are resolved. He includes among these issues the use of methanol and ethanol as straight fuels and other forms of non-gasoline-utilizing transportation, such as electric vehicles.

However, Terra looks favorably at methanol's prospects. "We think it is a

business that has good long-term growth because the basic economy is that much stronger," says Drissell. "If you took MTBE out of the equation, obviously you would have an effect, but overall, the business is just that much better than it was four to five years ago."

The anticipated growth in the market for methanol has led to consolidations of existing capacities, the startup of new capacity, and the entry of new companies into the business.

Terra, also a large producer and marketer of nitrogen-based fertilizers, entered the methanol business after converting 800,000 lb of its 3 million-lb-per-day ammonia plant in Woodward, Okla., to methanol production. The company says the $15.5 million methanol plant will have an annual capacity of 269 million lb.

Also, as part of its pending acquisition of Agricultural Minerals & Chemicals (AMC), a nitrogen fertilizer producer in Tulsa (C&EN, Aug. 15, page 6), Terra will receive Beaumont Methanol, formerly a DuPont facility. Beaumont, with a 1.85 billion-lb-per-year methanol capacity, was purchased by AMC and a minority partner, Transammonia, a French trading group.

Methanex became the world's largest marketer of methanol after acquiring Nova Corp.'s methanol plants in early 1994. In 1993, Methanex produced 4.65 billion lb in its five plants located in Canada, Chile, and New Zealand. It also marketed an additional 2.09 billion lb for other producers.

Methanex's Aitken says capacity will reach 7.72 billion lb in 1994, including the addition of Nova's existing capacity and partial contributions from two expansions. Methanex is expanding New Zealand capacity by 1.54 billion lb and has entered a 70-30 partnership with Cytec for 1.21 billion lb of methanol to be produced at Cytec's converted ammonia facility in Avondale, La. Methanol marketed for others will reach 3.31 billion lb in 1994, says Aitken. In 1995, Methanex's annual capacity is expected to reach 10 billion lb.

Saudi Basic Industries Corp. (SABIC), the Saudi Arabian industrial conglomerate, is the next largest methanol producer, with annual capacity of about 4.63 billion lb. Saudi Methanol, a 50-50 partnership between SABIC and a Japanese consortium led by Mitsubishi Gas Chemical, has a 2.65 billion lb annual capacity. National Methanol, a 50-50 partnership between SABIC and CTE Petrochemicals, which itself is a 50-50 joint venture between Hoechst Celanese and Panhandle Eastern, has annual methanol capacity of 1.98 billion lb. As of Jan. 1, SABIC's marketing subsidiary assumed 100% marketing responsibility for National Methanol's production. National Methanol also produces about 1.54 billion lb of MTBE annually.

Gulf Petrochemical Industries—a partnership between Saudi Arabia, Kuwait, and Bahrain—operates an 882 million-lb-annual-capacity methanol plant in Bahrain, with SABIC Marketing holding the selling responsibility for that output. During the year, Saudi European Petrochemical, also part of the SABIC conglomerate, upped its MTBE capacity to 2.65 billion lb from 1.1 billion lb.

When Hoechst Celanese restarts its Clear Lake, Tex., 1.32 billion-lb methanol plant—for which it is still seeking a partner—it will become the third largest methanol producer worldwide. Hoechst Celanese already operates a 1.1 billion-lb plant in Bishop, Tex., and owns 46% of Edmonton Methanol, a 1.65 billion-lb plant. Celanese Canada, which is 56% owned by Hoechst Celanese, holds the other 54% interest in Edmonton Methanol, which for the most part serves the merchant market in Canada, the U.S., and the Pacific Rim. However, Hoechst Celanese has placed its stake in Edmonton Methanol up for sale.

Hoechst Celanese, one of the largest producers of formaldehyde and acetic acid, uses over 1.5 billion lb of methanol captively in its production. The remaining methanol is sold on the merchant market.

Statoil, Norway's state-owned oil company, expects to open a 1.9 billion-lb-per-year plant in Tjeldbergodden, Norway, by late 1996. Another three projects are just in the planning stage, including a 1.6 billion-lb-per-year plant in Theodore, Ala., proposed by a partnership involving Methanol One and Degussa; a 1.45 billion-lb plant in Bontang, Indonesia, to be owned by Kaltin; and a 1.45 billion-lb plant on Kharg Island, Iran, which will be owned by Iran's National Petrochemical Co.

As summed up by Aitken, while the world may currently be short one or two methanol plants, with the addition of five or six, overcapacity could return. □

Alpha Olefins Answers

Eduardo J. Baralt, Ph.D.

Q. I am interested in producing alkyl silanes. What can you tell me about this chemistry?

A. The direct addition of silanes to alpha olefins is also known as hydrosilation of alpha olefins. It is catalyzed by peroxides, ultraviolet light or transition metal compounds. In most commercial processes, a silane such as Cl_3SiH reacts with an alpha olefin in the presence of a catalyst (chloroplatinic acid, H_2PtCl_6, molar concentration $\geq 1 \times 10^{-8}$) to make an alkylchlorosilane.

$$CH_2{=}CHC_{16}H_{33} + Cl_3SiH \xrightarrow[60 - 120°C]{H_2PtCl_6} Cl_3SiCH_2CH_2C_{16}H_{33}$$

$$\Delta H_{reaction} = -15 \text{ kcal/mole}$$

Other metals can catalyze this reaction, but chloroplatinic acid (CPA) is the preferred catalyst because of its high activity and low catalyst concentrations.

Olefin Order of Reactivity:
Alpha >> vinylidene > trisubstituted ≈ internal olefins

Side Reactions: The most common side reaction is the isomerization of alpha olefins to internal olefins. Low reaction temperatures (60 - 80°C) reduce isomerization.

$$CH_2{=}CHC_{16}H_{33} \xrightarrow{\text{CPA, Silane, 60 - 120°C}} CH_3CH{=}CHC_{15}H_{31}$$

The alkyltrichlorosilane is frequently reacted with an alcohol to make an alkyltrialkoxysilane:

$$Cl_3SiCH_2CH_2C_{16}H_{33} + 3\,ROH \rightarrow (RO)_3SiCH_2CH_2C_{16}H_{33} + 3HCl$$

Methanol, ethanol and t-butanol are the preferred alcohols since they can be readily removed when coating a surface:

$$(RO)_3SiC_{18}H_{37} + 3\,[Al\text{-}O\text{-}H]_{surface} \rightarrow 3\,[Al\text{-}O\text{-}]_{surface} \text{-}SiC_{18}H_{37} + 3ROH$$

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Chemical payrolls increased slightly last year

The U.S. chemical industry is generally not labor intensive. As a result, while the industry contributes about 1.9% of the U.S. gross domestic product, the salaries, wages, and dividends the chemical industry paid out in 1993—totaling almost $61.4 billion—made up just 1.1% of the total $5.26 trillion in personal income in the U.S. last year, according to the Department of Commerce.

The restructuring and downsizing in the chemical industry have taken a toll on personal income growth. The $61.4 billion paid out in 1993 for chemicals and allied products was 2.6% higher than the previous year. Growth in 1992 was almost three times higher at 7.4%. And growth for total personal income was 4.4% in 1993, down from 6.1% the year before.

Chemicals and allied products is well down on the list of industries in terms of contribution to total personal income. It is easily dwarfed by retail trade at $368 billion and, among the service industries, by health services at about $343 billion. However, among manufacturing industries in 1993, chemicals and allied products came in third following machinery and computer equipment, at $84.1 billion, and electronic equipment, excluding computers, at $63.3 billion.

Among the 50 states, New Jersey and Texas rank first and second in terms of personal income from chemicals, between them accounting for 22% of chemicals-derived income nationwide.

With New Jersey's large number of corporate headquarters providing higher paying jobs, and its concentration of the pharmaceutical industry, personal income from chemicals in the state last year was $6.86 billion, up a slight 0.5% from the previous year and accounting for 3.3% of total personal income for the state's residents.

New Jersey was followed relatively closely in total dollars by Texas at $6.43 billion. This accounted for 1.9% of total state personal income in Texas. Personal income from chemicals was up 4.5% in 1993 from the previous year.

Texas has perhaps the largest number of industrial chemical plants in the U.S. Although the Commerce Department provides no analysis of the data, the larger than average increase in personal income in Texas is perhaps a result of the larger percentage of production workers in the state—a segment of employment that has grown while white-collar jobs have declined.

Number three, Illinois, trailed the first two states by a wide margin with personal income from chemicals at $4.13 billion, up 4.8% from the previous year.

Although most of the states were in the less than 1 to 3% range in terms of chemical contribution to total state personal income, there is one standout. Delaware, perhaps not surprisingly considering the companies located there, had about $1.84 billion in personal income contributed by the chemical industry. This amount is 12% of the state's personal income and it makes chemicals the largest contributor. However, because of the reductions in employment at major Delaware chemical producers such as Hercules, ICI, and of course, DuPont, chemicals-derived personal income has declined. The dollar figure in 1993 was down 4.9% from 1992, which itself had been down 3.9% from 1991.

Besides Delaware, four other states had declines in personal income last year. Virginia was down 8.1% to $1.15 billion, Florida dropped 2.9% to $957 million, New York was off 2.6% to $3.44 billion, and Massachusetts fell 1.3% to $891 million.

William Storck

Most states had increases in chemical industry personal income

$ Millions	Personal income derived from chemicals	Percent change from 1992	Income from chemicals as % of state personal income
Alabama	$ 602	2.2%	0.8%
Alaska	28	7.7	0.2
Arizona	246	6.5	0.3
Arkansas	229	4.1	0.6
California	3,515	4.8	0.5
Colorado	554	2.2	0.7
Connecticut	1,349	1.7	1.5
Delaware	1,835	–4.9	12.1
Florida	957	–2.9	0.3
Georgia	847	5.6	0.6
Hawaii	19	0	0.1
Idaho	198	4.8	1.0
Illinois	4,134	4.8	1.6
Indiana	2,048	6.0	1.9
Iowa	299	5.3	0.6
Kansas	297	1.4	0.6
Kentucky	720	3.7	1.1
Louisiana	2,053	3.5	2.9
Maine	47	9.3	0.2
Maryland	671	5.0	0.6
Massachusetts	891	–1.3	0.6
Michigan	2,500	3.4	1.3
Minnesota	562	5.0	0.6
Mississippi	311	5.1	0.8
Missouri	1,548	4.1	1.5
Montana	$ 24	9.1%	0.2%
Nebraska	121	0.8	0.4
Nevada	38	0	0.1
New Hampshire	249	6.0	1.0
New Jersey	6,861	0.5	3.3
New Mexico	47	6.8	0.2
New York	3,436	–2.6	0.8
North Carolina	2,391	4.0	1.8
North Dakota	5	0	0.1
Ohio	4,123	6.5	1.9
Oklahoma	159	6.0	0.3
Oregon	114	7.5	0.2
Pennsylvania	3,790	1.8	1.5
Rhode Island	135	9.8	0.6
South Carolina	1,984	3.9	3.2
South Dakota	9	0	0.1
Tennessee	1,779	0.9	1.9
Texas	6,425	4.5	1.9
Utah	145	21.8	0.5
Vermont	26	4.0	0.2
Virginia	1,154	–8.1	0.8
Washington	326	12.0	0.3
West Virginia	906	0.1	3.1
Wisconsin	594	8.0	0.6
Wyoming	53	12.8	0.6
TOTAL	$61,354	2.6%	1.1%

Note: Personal income is made up of salaries, wages, and other labor income, dividends and interest, rental income, and government transfer payments such as social security, unemployment, and veterans benefits. **Source:** Department of Commerce

DEMAND

Rebecca L. Rawls, C&EN Washington

It's not exactly a groundswell. In fact, one observer says it's not even a light at the end of the tunnel, because it's not that big yet. It's more like a bit of light beginning to show through the cracks in a wall. But however it's phrased, the sentiment among many recruiters, chemistry department chairmen, college placement directors, and other close observers of chemical employment is that there will be more jobs for chemists graduating in 1995 than there were in 1994 or 1993.

However, the 1995 recruiting season, which gets under way this month, will still be a challenging one for job seekers. The recovery that observers are beginning to predict is from a very poor base; 1994, by many standards, was one of the worst years in two decades to be looking for a job in chemistry. And, as always, some degree levels and some fields of specialization will be more promising than others.

At the bachelor's level, most observers contacted by C&EN are calling the employment market not too bad, not great, but with jobs enough to go around as long as students are resourceful and spread their nets widely. For Ph.D.s and those in postdoctoral positions, the market—though improving—is expected to stay very tight for at least another year. The already swollen postdoctoral pool is likely to get even larger in 1995, growing in part because many newly graduating Ph.D.s will not be finding the permanent jobs they want in industry or academia. The effect of a slight increase in jobs is

ACS starting salary survey confirms tight market for newly graduated chemists

The job market was tight for chemists who received their degrees last winter or spring. For both new bachelor's level chemists and Ph.D.s, job offers were scarce and unemployment was high when compared with historic trends. Perhaps partly for this reason, the fraction of 1994 graduates deciding to stay out of the job market for a few more years by going to graduate school or taking a postdoctoral position remained high.

That's the picture to be drawn from the early data in ACS's most recent annual survey of newly graduated chemists and chemical engineers, conducted over the summer. Responses have been particularly slow in coming this year, says statistician and senior research analyst Joan S. Burrelli of ACS's Office of Professional Services, who directs the survey. Data for chemistry graduates are based on about 2,200 responses, or roughly one fifth of the people who received degrees in chemistry in the U.S. between September 1993 and June 1994.

For chemists with new bachelor's level degrees, just over half—52%—were planning to be full-time students this fall, with another 9% planning part-time advanced study. That's down slightly from 1993 and 1992, when 54% and 55%, respectively, of B.S. graduates were headed for full-time advanced study. This year, 30% of the bachelor's level chemists had full-time employment by mid-summer, and three out of four of them considered their work to be in chemistry. That leaves 16% seeking employment, up from 14% in 1993 and 9% in 1992. The last time the survey found such high unemployment among recently graduated bachelor's level chemists was in 1985.

Some 60% of those entering the work force with bachelor's degrees went to work in industry, with the remainder divided more or less evenly among colleges and universities, high schools, hospital and independent laboratories, and everything else. In that respect, the new graduates followed the general pattern of recent years. Their median salary—the salary met or exceeded by 50% of the individuals in the group—was $25,000, up from a median of $24,000 a year earlier. However, the movement of starting salaries, particularly at the B.S. level, is always a bit jerky. When the median changes, it often does so by $1,000, and this year's jump is the first change in two years for this figure.

A closer look at where the industrial jobs were for new bachelor's level chemists reveals some of the distinctive character of the 1994 job market. Of those going to work in industry, 29% found their jobs at pharmaceutical firms. The next largest group, with 21%, took nontraditional jobs for chemists—in industry, but not for manufacturing companies. Next came jobs with specialty chemical makers and with other types of manufacturers, which each provided 17% of the jobs found. Manufacturers of basic or agricultural chemicals and petroleum companies were essentially not hiring new B.S. chemistry graduates.

Almost half of B.S. chemistry graduates who went to work in industry found jobs at companies with fewer than 500 employees, and another 22% found work with companies with 500 to 2,499 employees. Only 15% went to big companies with 25,000 or more workers. Almost half of the inexperienced B.S. chemists who found work—48%—accepted the only job they were offered.

The job market for newly graduating Ph.D. chemists was, if anything, even tighter than that for B.S. graduates, according to the survey. By midsummer after their graduation, only 40% had found full-time employment. Essentially the same number—41%—had accepted postdoctoral fellowships, and another 17% were unemployed and looking for work. The rest were not seeking employment. Those numbers are almost the same as those for the previous year, when 41% had full-time employment, 41% had postdoctoral fellowships, and 16% were looking for work. It's small comfort, however, to say that 1994 wasn't any worse than 1993 for new Ph.D.s looking for work, since—until 1994 came along—1993 had been by most measures the worst year in more than a decade to be entering the job market with a Ph.D. in chemistry.

Unlike the bachelor's level, where 1994 salaries climbed a bit from their

dampened very considerably by the presence of that pool of postdocs, some of whom compete directly with new graduates for the positions whose numbers are just beginning to grow.

Still, the sentiment heard over and over from observers this fall is that there is some movement in the job market, and that movement is definitely in the right direction.

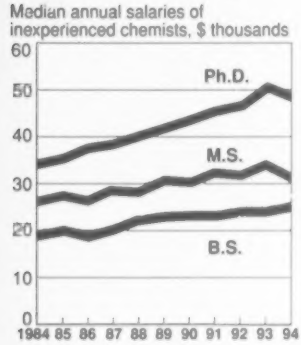
"Chemical companies, in particular, seem to be doing more hiring than they did last year," says Joel Shulman, manager of doctoral recruiting for Procter & Gamble. Dennis H. Guthrie, manager of university relations at Dow Chemical agrees. "I've spoken to a lot of my counterparts in the industry," Guthrie says, "and the hiring outlook for 1995 across the board in the chemical industry does indeed look like it's turning up." Both men are quick to point out, however, that hiring by chemical companies has been very low for the past two years, so that even though recruiting will be stronger for 1995 graduates, it will remain far below the levels of five to eight years ago.

Indeed, some close observers of industry recruiting estimate that the large chemical and diversified companies—those that might hire several dozen Ph.D. chemists in a single year—will be hiring about 30% more Ph.D. chemists in 1995 than they did in 1994. Five years ago, those same companies were hiring four times as many chemists as they did in 1994. So, although the percent change may look impressive, the numbers are still relatively small.

"We're seeing a little bit of activity," says Rebecca J. Simon, placement director for the school of chemical sciences at the University of Illinois, Urbana-Champaign, confirming the picture painted by corporate recruiters. "Some companies have come back to campus [on recruiting visits] that haven't been here for awhile. But instead of coming in for the major part of a week, like they used to, they are coming in for one day. I guess that's better than nothing."

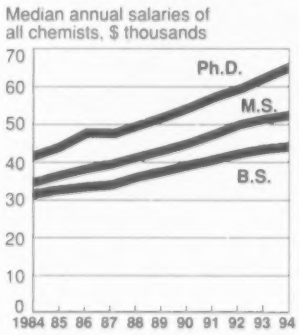
At the bachelor's and master's levels, 1995 isn't shaping up to be an easy year to find a job. However, it looks to be much better than 1994 has been, when 16% of new B.S. chemists were still seeking employment at midsummer, according to preliminary data from the American Chemical Society's annual survey of new chemistry graduates. That's the highest level of unemployment among new B.S. chemists that the survey has

Starting salaries for Ph.D. chemists slip . . .



Note: Data as of the summer of each year.

. . . as salaries for all chemists keep growing



Note: Data as of March of each year.
Source: ACS annual surveys

1993 levels, the newest crop of Ph.D. chemists were accepting slightly lower pay than their counterparts in the previous year. The median salary dipped to $49,100 for 1994 graduates, a drop of about 3% from the $50,400 median of 1993. Men, who outnumbered women by about 2 to 1, had a median salary of $52,000, 30% higher than that for women. That difference largely disappears, however, when the type of employer is taken into account. For those taking jobs in private industry, the median salary for men—$55,000—was within 1% of the median for women. These are very small samples, however, with only nine women and 29 men reporting salary information for jobs in private industry.

Another 20 new Ph.D. chemists took jobs at colleges and universities, where the median starting salary this year was $31,750, a substantial 13% more than the median had been in 1993. Although these salaries are much lower than what industry is paying entry-level Ph.D.s, they are not, in many cases, the best paying entry-level jobs for chemists in academia. By and large, tenure-track positions at Ph.D.-granting universities require postdoctoral experience.

At the master's level, the survey found 44% of new graduates intended to continue full-time study this year, which is typical for recent years. About the same number—46%—had found full-time employment, and 10% were unemployed and looking for work. Although down from the 12% who were looking for work a year earlier, such double-digit unemployment is unusual for new graduates at this degree level, just as it is for B.S. and Ph.D. recipients. The median salary for inexperienced M.S.-degree holders fell to $30,000, down 12% from 1993, and back to the median amount new master's degree chemists were earning in 1990.

The College Placement Council (CPC) also collects data on starting salary offers made to newly graduating chemists. This year, it finds the median offer for new Ph.D. chemists to be $53,100, down $900 or 2% from last year's median. For B.S. chemists, this year's median of $27,500 is down $775 or 3% from last year's level. Because of differences in the way the two surveys are conducted, the CPC survey generally finds salaries a bit higher than the ACS survey does.

The complete ACS report, "Starting Salaries 1994," will be available later this year for $29.95 per copy from the Product Services Department, American Chemical Society, 1155—16th St., N.W., Washington, D.C. 20036. Questions or comments should be directed to Joan Burrelli at (202) 872-4433.

found since 1985. (For additional information from this survey, see box above.) "I would say [1995 will be] a competitive, but not outrageous, situation for the graduating B.S. chemist," says James D. Burke, manager of research recruiting and university relations at Rohm and Haas, summing up the view of many observers. "What the B.S. chemists do not have working against them is a big postdoctoral pool," he adds.

Recruiting at the Ph.D. level will be very selective this year, many observers say. "I think companies are looking very closely at what their needs are and trying to meet those, rather than having the ability to look for good people in a variety of areas, figuring that they can find a place for them," says Kenn E. Harding, chemistry professor and graduate adviser at Texas A&M University. "Recruiters are being very cautious," Simon agrees. "They are looking for somebody with specific skills, and they want people right now. When [a work unit within a company] finally gets a position to fill, they need a person in it immediately." That makes job hunting hard for Ph.D. candidates, she points out, who frequently interview as much as a year and a half before they expect to complete their degree requirements.

As has been true for the past several years, the favored fields for Ph.D. chemists this year seem to be analytical chemistry and synthetic organic chemistry, particularly those specializations within each field that are attractive to pharmaceutical companies. Drug companies have become the major employer of Ph.D. chemists who go to work in industry, claiming 39% of new chemistry Ph.D.s going directly into industry in both the 1993 and 1994 academic years, according to ACS's annual surveys. Prior to that, when chemical and diversified manufacturing companies were hiring more Ph.D. chemists, the pharmaceutical industry still hired a quarter to a third of each year's graduates who went directly into industrial jobs.

Pharmaceutical companies hire a significant number of chemistry postdocs, as well. In fact, several observers point out that although part of the reason for the growing number of chemistry Ph.D.s in postdoctoral positions is the poor job market for new graduates, another important reason is the preference many pharmaceutical companies have for hiring people with three or four years of postdoctoral experience when hiring for entry-level research positions. By con-

trast, when chemical companies hire postdocs or when universities do, they usually want people with two years of postdoctoral experience. Thus, the growing importance of the pharmaceutical industry as an employer of chemists is another reason for people to stay longer in postdoctoral positions.

These two forces have combined to swell the pool of chemistry postdocs to levels estimated by some observers as being as high as 4,000 to 4,300 people. That's the equivalent of two years' worth of Ph.D. graduates and may be twice the number of those who were in such positions a decade ago.

At the other end of the demand spectrum for Ph.D. chemists are the physical chemists, who, like their colleagues coming out of physics departments, face a very tight job market. Largely because of cutbacks in spending by the Department of Defense, jobs for physicists and physical chemists at both national laboratories and Defense Department contractors are very scarce. "Because defense industries are downsizing, the spectrum from physical chemistry all the way over into physics has become a fairly tight, if not bleak, area of employment," confirms Bruce Ganem, chemistry department chairman at Cornell University.

The difference in the employment prospects for different types of Ph.D. chemists is beginning to cause some strain at universities, says Robert J. Sibley, chemistry department chairman at Massachusetts Institute of Technology. "In chemistry departments, you have a span from biochemists and even some biotechnologists all the way over to physical chemists and people who might even be thought of as physicists. The biochemists are not having trouble getting jobs. They may not be getting the perfect job, but they are getting jobs. Whereas the physical chemists, especially the ones more and more into the physics side, are in really much deeper trouble. That's just the way the market is, but it makes problems in the department, because for some people the world is fine, and for other people it's not so fine."

For many chemical companies, 1993 was a profitable year and 1994 is shaping up to be another one. That, in a nutshell, seems to be what's allowing them to cautiously step up their hiring. In addition, the downsizings that have been widespread among large companies of all types in the U.S. in the past few years seem to be easing off. Although new announcements of staff reductions at companies where chemists work are still being made, these announcements seem to be coming less frequently than they were a year or two ago. A recent survey by the American Management Association found that during the year that ended in June, 45% of major U.S. manufacturing companies reduced their work force, down from 56% that had done so two years earlier.

In the 1994 survey, manufacturing for the first time trailed all other major business sectors—such as financial services and retail trade—in the fraction of companies that had had work force reductions. More directly relevant to chemists are data from the Pharmaceutical Research & Manufacturers of America, which find that reductions totaling 8,130 jobs have been announced by its member companies so far in 1994, down from 23,000 for all of 1993.

"I think what I would call the batch process of terminations seems to be coming to an end," says Rohm and Haas' Burke. "You will continue to see people regularly leaving as companies continue to streamline, but I don't think they will be in the great numbers that we have seen, at least not in the chemical companies."

Dow Chemical expects to hire more chemists and chemical engineers in 1995 than it did in 1994, when the company was in the midst of a substantial downsizing. "We will be on campus recruiting for full-time hires at the Ph.D. level," Guthrie says. By far, the majority of chemists hired by Dow are at the Ph.D. level, he points out. The company will also be recruiting engineering undergraduates for summer intern and co-op programs. "We're keeping those programs very strong, and we will be recruiting quite actively for those individuals on a large number of campuses," Guthrie says. The program is so strong, he adds, that he expects all of Dow's bachelor-level engineering hiring to come from this group.

Union Carbide will be back on campuses recruiting this fall, after not doing so for 1994 graduates, according to Donald E. Gatewood, manager of recruitment and college relations. "As we did last year, we will be making full-time employment offers to the graduating seniors in our student employment program who meet our discipline, academic, and performance criteria. In addition, we will be recruiting on the campuses where we normally recruit," he says, looking primarily at the bachelor's level for chemical engineers. The company will also be aiming to hire more Ph.D. chemists than it did last year.

On the other hand, Rohm and Haas, which is currently in the midst of reducing its staff, will not be doing much hiring of new graduates this year. "We are trying to deal with our restructuring through internal placements," Burke says. "It's just not an appropriate climate to bring people in from the outside when

More B.S. chemists, fewer Ph.D.s graduating

	Degrees awarded in chemistry[a]			Degrees awarded in chemical engineering[b]		
	Bachelor's	Master's	Ph.D.	Bachelor's	Master's	Ph.D.
1978	10,350	1,798	1,532	4,225	1,019	251
1979	10,451	1,716	1,532	4,977	951	237
1980	10,170	1,698	1,561	5,348	974	243
1981	10,453	1,609	1,613	5,831	1,020	250
1982	9,866	1,645	1,683	5,963	1,171	293
1983	10,043	1,569	1,759	7,021	1,317	333
1984	9,819	1,637	1,777	6,866	1,436	357
1985	9,679	1,621	1,806	6,442	1,489	418
1986	9,295	1,620	1,885	5,229	1,244	460
1987	8,848	1,636	1,936	4,435	1,078	533
1988	8,372	1,584	1,955	3,524	1,036	603
1989	8,125	1,710	1,970	2,891	919	574
1990	7,650	1,605	2,131	3,170	956	583
1991	7,782	1,600	2,213	3,087	821	602
1992	8,435	1,617	2,202	3,060	769	539
1993	8,800	1,683	2,140	3,164	705	435

a Awarded by chemistry departments offering an ACS-approved bachelor's level program.
b Chemical engineering departments are not required to report their degrees to ACS, so the number doing so varies from year to year. **Source:** ACS Committee on Professional Training

there's a high level of anxiety [among staff members]."

"We will definitely be doing a reasonable amount of hiring of Ph.D. chemists, as we did last year," says Procter & Gamble's Shulman. The company's hiring will be up this year for bachelor's and master's level chemists, as well, he adds.

Although by far the majority of people contacted by C&EN thought the employment picture for 1995 looked better than that for 1994, some were less sanguine. "My impression so far is that we still have a reduced number of [company recruiters] coming through," says Kenneth N. Raymond, chemistry department chairman at the University of California, Berkeley. Last year, Raymond says, some recruiters came on what he describes as "courtesy calls, really, just to keep in touch, not hiring anybody." As for this year, he says, "So far I don't see any dramatic improvement." Nor does Cornell's Ganem. "We are concerned that the employment picture for Ph.D.s looks tighter and more limited than it did last year," he says, "although I'm actually fairly optimistic that our department will do fairly well in placing people." At Texas A&M, too, recruiting visits are expected to be "less than or equal to" last year's levels, Harding says. "I would not expect more."

Mary L. Funke, head of ACS's Department of Career Services, says: "Employers are always seeking talent and so are interviewing. But actual hiring is pretty much the same as last year." Funke bases her assessment in part on activity at ACS's most recent National Employment Clearing House, held in conjunction with the ACS national meeting in August in Washington, D.C. Late summer meetings and those in northeastern cities always draw the largest numbers of job seekers to the clearinghouse, points out Anjalika Silva, staff associate responsible for the National Employment Clearing House, and the August meeting was no exception, with a record 1,505 candidates on site looking for jobs. Only 125 employer organizations registered to interview them, down from 139 at the spring 1994 meeting in San Diego and from 143 the previous August in Chicago. "Although there were fewer employers at the Washington meeting, the number of interviews was up from the spring meeting," Silva says.

The most reasonable base for comparing activity at the recent clearinghouse, however, is probably the August 1992 national meeting, which was also held in Washington. Compared with that meeting, the most recent clearinghouse had 30% more job candidates interviewing with 25% fewer companies. Actual interviews were down 41% from two years ago and the number of jobs posted was down 38%. Moreover, Silva says, the mood at the most recent clearinghouse was decidedly downbeat. "What you hear from the candidates is that the job situation is bad," she says. "They are finding it difficult to get a job. And from the point of view of the employers, we find that some of them do come and interview, but they are not exactly ready to hire. They are kind of testing. There are some who have actual jobs, but there are others who are just keeping in touch."

This past summer, ACS's Department of Career Services conducted extensive interviews with more than 100 employers of chemical professionals including corporate vice presidents of R&D, division directors, company presidents, and chairmen of chemistry departments at universities. The purpose was to identify trends in technology and in the economic climate that will affect the chemical workplace over the next few years. Interviewers also asked about hiring plans for 1995 and beyond.

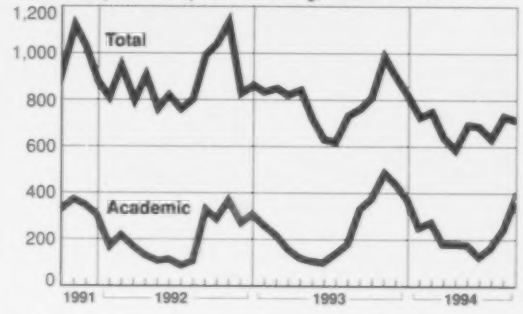
Although the full report of the study will not be completed until later this year, some things can already be gleaned from it. The study found, for example, that the hiring plans of companies vary greatly depending on company size. Companies with 500 or fewer employees were anticipating an increase in hiring, while large companies, with more than 10,000 employees, expected to maintain or decrease staff size. Most of the people interviewed said that the downsizings among employers of chemists are mostly over. And even those companies that plan to hold staff size steady or to decrease it will be doing some hiring for replacement or to obtain a different mix of skills among employees.

Most of the small companies included in the study were optimistic about the future. They are hiring now and plan to continue to do so, with a typical company planning to increase staff by 10 to 20% over the next several years. However, because the companies themselves are small, a 20% increase may mean only five or six more people. Most of the hiring at these small companies is for B.S. chemists, preferably with a few year's work experience. Such people need less on-the-job training than new graduates. The small companies are looking for broadly based generalists to help run their businesses. They need entrepreneurs and people who can tackle a broad base of challenges.

Some medium-sized companies in the survey were not planning to expand in the next few years; others expected growth of as much as 5%. None was expecting to decrease staff. These companies are hiring chemists at all degree levels, as well as chemical engineers. The B.S. chemists are mainly being hired as technicians and the Ph.D.s mostly for R&D.

The relative strength of smaller companies as employers of chemists has been apparent in the job market for several years, and many people contacted by C&EN report that there are very promising opportunities for chemists to be found there. For example, Dennis C. Liotta, chemistry department chairman at Emory University in Atlanta, says small companies that are just getting started are a student's "best option right now because there are so many of them around. They proliferate."

C&EN's help-wanted ads give no clear sign of hiring recovery



[a] Column-inches published during consecutive periods of four weeks each.

In addition, he says: "If you go into a startup company, especially a relatively new one, you have an opportunity and a degree of visibility that are tremendous compared with a traditional chemical or pharmaceutical company. You may be one of 20 scientists, as opposed to one of 400 scientists [in a larger company]. And if you go in at the ground floor, your [employment] package will probably include stock options. So if the company is sucessful, you can do very, very well financially, and you can do very well professionally. If the company is unsuccessful, you still probably will have five year's worth of good experience.

"Many times in a small company, you have to be more versatile, more diversified in the things you do, and for many people, that's attractive. I think someone who works for a startup company for five years probably has good training and probably has at least as good a chance of getting another job as anyone else. If the company is successful, they probably get promoted much more rapidly than they would in a large company, and they get much better financial rewards."

Rohm and Haas' Burke offers another reason why chemistry Ph.D.s and postdocs may find themselves well suited for taking jobs at small companies: The "culture" of these companies, he says, is very like that of academic research. "The typical research professor is an entrepreneur," Burke says. "He or she goes out and raises capital—that is to say, applies for grants—and then employs people on different kinds of projects that are, in some cases, speculative; certainly all of them are fairly daring. There's a mentality that the postdocs and the graduate students absorb that makes their going to these smaller companies a fairly easy transition."

However, Burke and others point out that it takes a great many small companies, each hiring only three or four chemists a year, to make much of a dent in overall chemical employment. In fact, MIT's Sibley points out that last year his department had more company representatives come to interview students than ever before, but, because a lot of them were from smaller companies, the overall number of jobs they were offering was actually smaller than usual. He expects the same situation this year.

How academic employment is shaping up for 1995 is much harder to tell. A spot check at 10 chemistry departments around the country finds much the same range of sentiments that have been heard for several years. Almost all chemistry departments contacted by C&EN were hoping to fill at least one position in the coming year. The reasons for that are clear: Undergraduate chemistry enrollments are rising and many faculty are reaching retirement age. Several departments say they have still not found the candidate they want to fill positions that have been open since last year, despite receiving several hundred applications for each opening.

Yet many chairmen still report that academic employment is very tight. At the University of California, San Diego, for example, nine chemistry faculty will be retiring this year, thanks to a particularly generous retirement package the university is offering in an attempt to reduce its overall staff. That's roughly one fifth of the entire department, yet the department expects to be able to replace only one or two of them, despite increasing undergraduate enrollments.

"Private universities are [also] having to tighten up," says Jeremy K. Burdett, chemistry department chairman at the University of Chicago. "Our chemistry faculty almost certainly will shrink. . . . We're recruiting, but we are not going to be able to recruit as aggressively as we should be to make up for retirements and losses."

But the picture looks better at some departments. "During these difficult economic times, we've actually been able to maintain an influx of new young faculty," says Joseph L. Templeton, chairman of the chemistry department at the University of North Carolina, Chapel Hill. "We got a 6% salary increase for faculty this year, after years of zero and 1% increases, so that was a big improvement. But while we were getting that, there were cuts to the College of Arts & Sciences for supplies." He adds: "I think the number of academic openings is holding constant or increasing."

MIT's Sibley doesn't think so. "Some of our very good students and postdocs are ending up in schools that are good schools but are not the strong research universities where I think most of our people, if they want to go into academic work, want to end up," he says. "These people would have had different choices 10 years ago."

One avenue that some chemistry Ph.D.s seem to be taking is to accept faculty positions at smaller, non-Ph.D.-granting universities or colleges instead of heading for a postdoc. These are jobs that involve supervising student research as well as teaching. Several department chairmen reported 1994 graduates who had opted for this route. Emory's Liotta speculates that students are attracted to such positions not because of the scarcity of faculty postions at Ph.D.-granting universities, but rather because the prospect of becoming a junior faculty member at such universities has become unappealing. "With the funding situation as tight as it is, and students knowing that there's essentially a direct link between getting funded and getting tenure [at a major research university], I think a lot of people are reluctant to get into the fray," he says. □